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Catch and Effort Statistics for the Sockeye Salmon Sport Fishery During the Late Run to the Russian River With Estimates of Escapement, 1991

by

Larry E. Marsh

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

A direct expansion creel survey of the late-run Russian River recreational fishery was conducted in 1991 to determine angler effort for and harvest of sockeye salmon *Oncorhynchus nerka*. Anglers expended 78,849 angler-hours to harvest 31,449 sockeye salmon from the late run (29 July-19 August). The weighted harvest rate for the late run was 0.399 sockeye salmon per hour of angler effort. Approximately three of every four fish harvested during the late run were taken from the confluence area of the fishery.

A total of 78,175 sockeye salmon bound for spawning areas were counted through the weir at the outlet of Lower Russian Lake during the late run. This total exceeds the escapement goal of 30,000 that has been established for the late run.

Predominant age groups in the escapement for the late run were 2.2, 1.2, and 2.1. The majority of these fish were age 2.2 (40.9%). The harvest was also sampled for age structure. The age structure of the harvest was similar to that of the weir in that it was comprised of the same three age groups. The late-run harvest was comprised primarily of age-2.2 adults. The age compositions of both the confluence area harvest and the river area harvest differed from that of the weir and from each other during some temporal components of the late run. Weighted estimates of the age composition for the total late return (apportioned harvest plus escapement) indicate that the late run was comprised primarily of age-2.2 and age-1.2 sockeye salmon (42.5% and 20.3%, respectively).

A stream survey indicated that a minimum of 22,267 sockeye salmon spawned in the Russian River downstream from the Russian River falls. Carcass sampling indicated that the most abundant age group (1.3) comprised 63.2% of the population that spawned downstream from the falls.

KEY WORDS: Russian River, sockeye salmon, *Oncorhynchus nerka*, creel survey, direct expansion, harvest, effort, weir, escapement, age composition, recreational fishery, mean length at age, harvest rate.

INTRODUCTION

The Russian River is a clearwater stream located in the central Kenai Peninsula near Cooper Landing, Alaska. The drainage includes two large clearwater lakes, Upper and Lower Russian lakes, and terminates in the Kenai River approximately midway between Kenai and Skilak lakes (Figure 1). The largest recreational fishery for sockeye salmon *Oncorhynchus nerka* in Alaska occurs in the Russian River and at its confluence with the Kenai River. Annual effort by anglers in this fishery during the early and late runs has exceeded 450,000 angler-hours and annual harvests have exceeded 190,000 fish. Prior information pertaining to this fishery has been presented by Lawler (1963, 1964), Engel (1965-1972), Nelson (1973-1985), Nelson et al. (1986), Athons and McBride (1987), Hammarstrom and Athons (1988, 1989), Carlon and Vincent-Lang (1990), and Carlon et al. (1991).

Late-run sockeye salmon of Russian River origin have also been harvested by a sport fishery in the mainstem Kenai River, a personal use dip net fishery in the Kenai River, and a commercial fishery in upper Cook Inlet. Recently established subsistence dip net and set gill net fisheries which may supplant or replace the personal use dip net fishery may also intercept late-run Russian River stocks in future years. Estimates of the total harvest of sockeye salmon by sport fisheries in the mainstem of the Kenai River have been reported annually since 1977 by Mills (1979-1991). The personal use dip net harvest has been estimated in the Statewide Harvest Survey since 1983 (Mills 1984-1990). The commercial catch and total return of sockeye salmon to the Kenai River have been reported by Cross et al. (1983, 1985, 1986).

Sockeye salmon return to the Russian River in two temporal components, termed early and late runs. Historically, the total return during the late run has numbered nearly twice that of the total return during the early run. The late run typically arrives at the Russian/Kenai River confluence in mid to late July. Late-run fish typically move immediately into the Russian River and are present in the area open to fishing through August. Late-run fish are comprised of two segments based upon spawning location: (1) those spawning upstream of the Russian River falls, and (2) those spawning downstream from the falls. While most fish migrating through the falls spawn in Upper Russian Lake, others spawn in the tributaries to Upper Russian Lake and in the river section between the upper and lower lakes. These fish are primarily 2-ocean fish and rear in the two lakes.[1] The other segment spawns in the Russian River downstream from the falls. These fish, which are primarily 3-ocean fish, are more closely associated with the age structure of sockeye salmon spawning in the mainstem Kenai River (Cross et al. 1983, 1985, 1986) and are believed to spend their freshwater residency in Skilak Lake.

The Division of Sport Fish of the Department of Fish and Game manages the recreational fishery to ensure that a minimum number of spawning sockeye salmon for the late run pass through a weir at the outlet of Lower Russian Lake (Figure 2). The current escapement goal, which was established in 1979 for the late run, is 30,000 fish. This goal is based upon evaluation of returns from past brood years. With the exception of one year, this escapement number has been achieved during each year since 1975. Despite an

[1] Juvenile sockeye salmon have been captured in nets in both lakes.

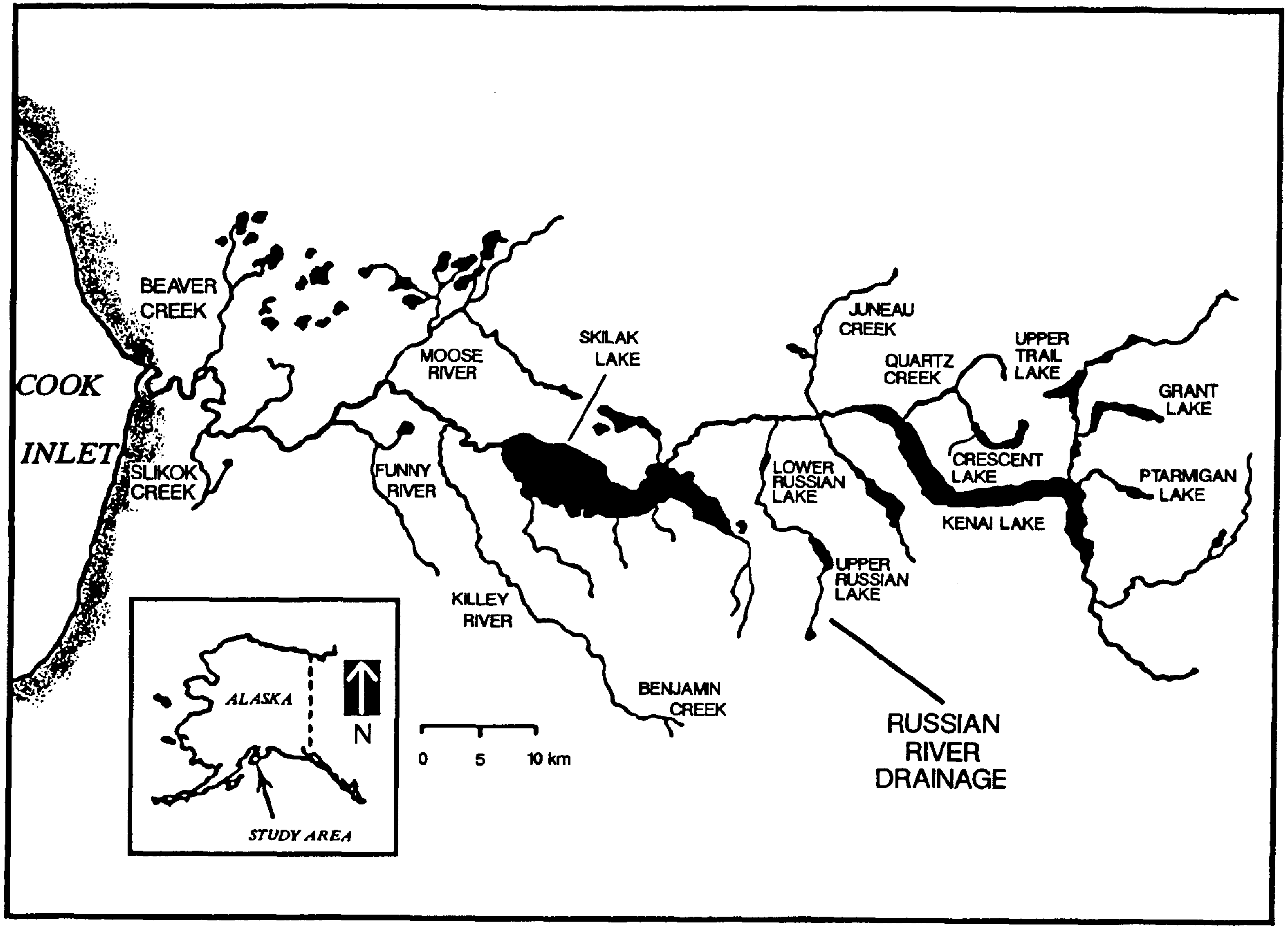

Figure 1. Map of the Kenai and Russian River drainages.

CONFLUENCE OF KENAI and RUSSIAN RIVERS

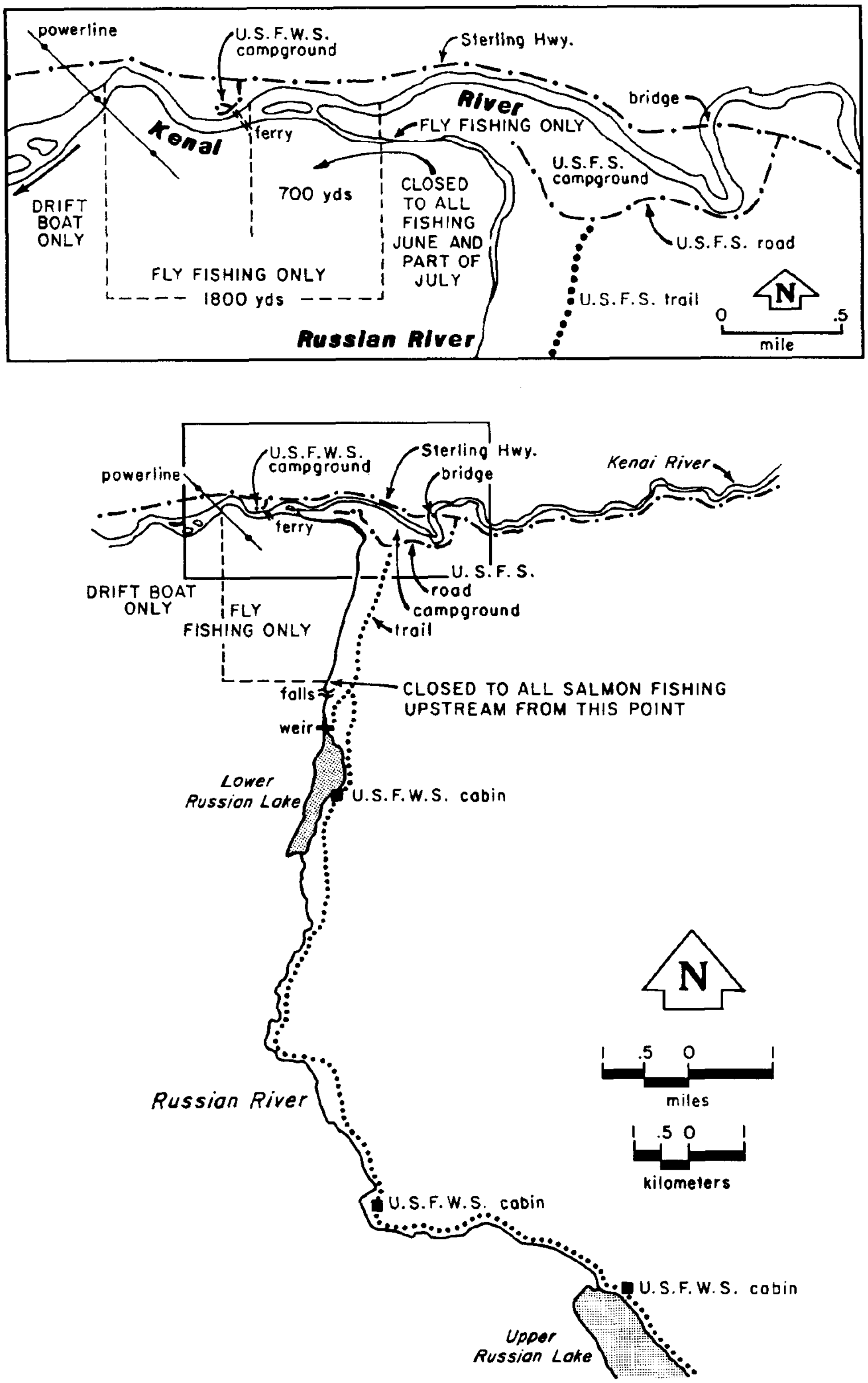

Figure 2. Detailed map of the Kenai and Russian River study area.

emergency closure of the late-run fishery in 1977, the escapement number was less than 30,000 fish (21,410) (Nelson 1978).

Given that the recreational fishery for sockeye salmon at the Russian River is the largest in the state in terms of angler effort, there is a potential for overharvest. Precise and timely management decisions are required to ensure that adequate escapement is obtained. The data necessary for these decisions are provided by a creel survey and a counting weir. The creel survey provides data regarding angler effort and harvest for the recreational sockeye salmon fishery which occurs in the Kenai/Russian River "fly-fishing-only" area (Figure 2). Weir operations provide daily escapement. Estimates of the total inriver return (harvest plus escapement) and the age, sex, and size compositions of the return provide information used to evaluate production and to estimate optimum spawning escapement levels.

From 1 June through 20 August 1991, the daily bag and possession limit for sockeye salmon taken from the Kenai/Russian River fly-fishing-only area was three fish of 406 mm (16 in) or more in length. Within this area, from a marker located 540 m (600 yd) downstream from the Russian River falls to a marker located on the Kenai River 1,620 m (1,800 yd) downstream from the confluence with the Russian River, only a single-hook unbaited, unweighted fly with a point-to-shank measurement of 9.5 mm (3/8 in) or less constituted legal terminal tackle. Any weights attached to the line were required to be a minimum of 457 mm (18 in) above the hook.

The objectives of this report are to present for 1991: (1) estimates of effort and harvest of late-run sockeye salmon for the recreational fishery, (2) estimates of the escapement of the late run of sockeye salmon, and (3) estimates of the age, sex, and length distributions of the harvest and escapement of the late run of sockeye salmon.

METHODS

Study Area

The recreational fishery occurs in two areas: (1) the confluence area, which extends from the upper limit marker of the sanctuary area[2] downstream approximately 1.6 km to a marker on the Kenai River identifying the downstream limit of the "fly-fishing-only" area; and (2) the river area, which extends from the upper limit of the sanctuary area upstream approximately 3.2 km on the Russian River to a marker identifying the upper limit of the "fly-fishing-only" area.

Access to the two fishing areas is provided primarily at two locations. A United States Forest Service (USFS) campground located on the east side of the Russian River provides four short trails which intersect the main riverside trail affording access to the river area. The trails serve four camping/parking areas within the Russian River Campground. These areas are

[2] The sanctuary area begins in the Russian River 137 m upstream of the confluence with the Kenai River and extends downstream to a marker placed approximately 25 m (75 ft) downstream of the ferry cable (approximately 640 m).

designated with the following names: (1) Grayling, (2) Rainbow Trout, (3) Pink Salmon, and (4) Red Salmon. Access to the confluence area is primarily through a parking area administered by the United States Fish and Wildlife Service (USFWS) and located on the north bank of the Kenai River directly across from the Russian River confluence. Immediately adjacent to the USFWS parking area is a cable ferry which traverses the Kenai River. Most anglers fishing the confluence area use the ferry to reach the south bank of the Kenai River. Both the parking area and the ferry are operated privately under a concession administered by the USFWS. Some anglers also use the ferry to cross the Kenai River and then walk upstream to fish the Russian river area. Anglers may also use one of the four USFS campground trails to gain access to the confluence area via the riverside trail which terminates at the confluence area.

A stationary weir, constructed of metal and wood, is located just downstream from the outlet of Lower Russian Lake and approximately 360 m (400 yds) upstream from the Russian River falls. The weir has been described in detail by Nelson (1976) and provides a complete count of the late-run spawning escapement.

Study Design

Creel Survey:

A direct expansion creel survey design was again utilized during the 1991 late run. Previous concerns with biased harvest and effort estimates (Carlon and Vincent-Lang 1990) obtained with a stratified roving creel design (Neuhold and Lu 1957) necessitated a change in creel design for the 1991 season.

Sampling was stratified by access location to estimate harvest and effort. Area-specific (river or confluence area) harvest and effort were estimated by recording the area fished for each interviewed angler. The five main access locations for the Russian River sockeye salmon fishery included the ferry access to the confluence area and the four river trails connecting the USFS Russian River Campground with the Russian River. These locations were sampled over one temporal component to provide a stratum estimate of sockeye salmon harvest and angler effort during the late run. The sampling dates were 29 July to 19 August.

The creel survey sampling day was 18 hours in length and was divided into six, 3-hour periods from 0600 to 2400 hours. A three-stage sampling design was used with days as primary units, periods as secondary units, and anglers as tertiary units. Days were systematically sampled, and within each sampled day, two 3-hour periods were randomly selected from the possible six. During each sampled period, anglers were interviewed as they exited the fishery through a sampled location. Thus, all interviews were of "completed-trip" anglers. All anglers exiting an access location during a sampled period were counted and as many as possible were interviewed for harvest and effort data by area fished (river area or confluence area). Anglers exiting a location during a sampled period and not interviewed were assigned as river or confluence anglers based on proportions determined from anglers that were interviewed. Count and interview data were then expanded for each stratum to account for area-specific harvest and effort during periods and days that were not sampled.

In 1990, approximately three-fourths of the harvest and effort occurred in the confluence area during the late run (Carlon et al. 1991). This is typical of the effort distribution in most years (Nelson et al. 1986). As a result of this concentration of harvest and effort and because harvest rate (harvest per hour) is used as a management tool to index sockeye salmon abundance at the confluence, the confluence access location (the ferry) was sampled every other day throughout the late run. This ensured that timely information regarding confluence harvest rates was available when formulating inseason management strategies.

In 1990, all river access locations were sampled equally as no prior information was available concerning angler use patterns. Results from 1990 showed that there were significant differences in the level of use among locations (Carlon et al. 1991). Two access locations, Grayling and Pink Salmon, are at parking lots and the anglers exiting at these two locations represented 60% and 27% of the total number exiting the river. Anglers exiting at these locations contributed 44% of the total harvest, but accounted for 74% of the variance surrounding the estimate of total harvest.

In an effort to reduce the overall variability of the estimates, a shift in the systematic sampling scheme was implemented in 1991 during the late run. Estimated population variances were used to optimally allocate the possible number of sampling days among the river access locations (Cochran 1977). These optimal sample sizes were adjusted so that no exit location was sampled fewer than four times during the late run. With only 1 year of data available, it was considered necessary to maintain this minimum level of sampling at all locations. During the late run, Grayling was sampled every 3 days, Rainbow every 9 days, and Pink Salmon and Red Salmon every 6 days.

The following formulae were applied to generate harvest and effort estimates for each spatial/temporal component of the fishery. At access location h, on day i, and during sample period j, a total of m_{hij} completed anglers were interviewed as they exited through location h. Anglers a_{hij} were "missed" anglers because they exited and were counted but were not interviewed. Interviewed anglers could be assigned to one of three groups:

m_{1hij} = anglers that fished the river area only,

m_{2hij} = anglers that fished the confluence area only, or

m_{3hij} = anglers that fished both areas, and

$$m_{hij} = m_{1hij} + m_{2hij} + m_{3hij}. \qquad (1)$$

To account for area-specific harvest attributable to missed anglers (a_{hij}), this group was assigned as having fished either the river area or the confluence area. The proportion of missed anglers that fished the river was estimated as:

$$\hat{P}_{rhij} = \frac{m_{rhij}}{m_{hij}}, \qquad (2)$$

where:

m_{rhij} = the number of interviewed anglers fishing the river = $m_{1hij} + m_{3hij}$.

The number (a_{rhij}) of missed anglers assigned as fishing the river was estimated as:

$$\hat{a}_{rhij} = (a_{hij})(\hat{P}_{rhij}). \tag{3}$$

The total number of anglers fishing the river area and exiting the fishery at location h, on day i, during sample period j, was estimated as:

$$\hat{M}_{rhij} = m_{rhij} + \hat{a}_{rhij}. \tag{4}$$

The same procedure was used to prorate the missed anglers who fished the confluence area:

$$\hat{M}_{chij} = m_{chij} + \hat{a}_{chij}. \tag{5}$$

The mean river area harvest per interviewed angler was:

$$\bar{h}_{rhij} = \frac{\sum_{l=1}^{m_{rhij}} h_{rhijl}}{m_{rhij}} \tag{6}$$

where:

h_{rhijl} = the river area harvest for angler l at location h, on day i, during sample period j.

The variance of river area harvest among interviewed anglers was estimated assuming a normal variate as:

$$\hat{s}^2_{3rij} = \frac{\sum_{l=1}^{m_{rhij}} (h_{rhijl} - \bar{h}_{rhij})^2}{m_{rhij}-1}. \tag{7}$$

The total river area harvest exiting with anglers through access location h, on day i, and during sample period j (H_{rhij}) was estimated as:

$$\hat{H}_{rhij} = \hat{M}_{rhij}\,\bar{h}_{rhij}. \tag{8}$$

The mean river area harvest per period ($\bar{H}_{rhi}$) is then estimated for day i and location h as:

$$\bar{\hat{H}}_{rhi} = \frac{\sum_{j=1}^{u} \hat{H}_{rhij}}{u} \qquad (9)$$

and the variance among sample periods is estimated as:

$$\hat{S}^2_{2rhi} = \frac{\sum_{j=1}^{u} (\hat{H}_{rhij} - \bar{H}_{rhi})^2}{u - 1}. \qquad (10)$$

The total river area harvest exiting with anglers through access location h, on day i was estimated by expanding the mean river area harvest per period on day i as:

$$\hat{H}_{rhi} = U \overset{\triangle}{H}_{rhi} \qquad (11)$$

where:

U = the total number of periods in a day (6).

The mean river area harvest per day ($\bar{H}_{rh}$) is then estimated for location h as:

$$\overset{\triangle}{H}_{rh} = \frac{\sum_{i=1}^{d} \hat{H}_{rhi}}{d} \qquad (12)$$

where:

d = the number of days sampled.

The variance of river area harvest among days (S^2_{1rh}) at location h is estimated using the variance for a systematic sample (Wolter 1985) as:

$$\hat{S}^2_{1rh} = \frac{\sum_{i=2}^{d} (\hat{H}_{(i)} - \hat{H}_{(i-1)})^2}{2(d-1)}. \qquad (13)$$

The total river area harvest for location h (H_{rh}) was estimated by expanding the mean harvest per day as:

$$\hat{H}_{rh} = D \overset{\triangle}{H}_{rh} \qquad (14)$$

where:

D = the total number of possible sampling days during a temporal component.

For any location h, the variance of the total river area harvest was estimated as:

$$V(\hat{H}_{rh}) = (1-f_1)\, D^2 \frac{\hat{S}^2_{1rh}}{d} + D \frac{U^2}{u} (1-f_2) \frac{\sum_{i=1}^{d} \hat{S}^2_{2rhi}}{d}$$

$$+ D_{rh}\, U \sum_{i=1}^{d} \sum_{j=1}^{u} M^2_{rhij} (1-f_{3rhij}) \frac{\hat{S}^2_{3rhij}}{d\, u\, m_{rhij}} \qquad (15)$$

where:

f_1 = the finite population correction factor for days (d_{rh}/D_{rh}),

f_2 = the finite population correction factor for periods (u_{rhi}/U_{rhi}),

f_{3rhij} = the finite population correction factor for anglers (m_{rhij}/M_{rhij}).

This procedure (Equations 2 through 15) was also used to generate estimates of the confluence area harvest exiting with anglers through each access location. Likewise, the same procedure was used to estimate angler-hours of effort expended in the river area or the confluence area by substituting the area-specific hours of effort reported by interviewed anglers for the reported harvest in Equations 2 through 15.

Daily harvest rates were estimated and used for inseason management as an indicator of sockeye salmon abundance. The daily confluence area harvest rate was based on interviews of anglers exiting the fishery through sampled locations and reporting confluence targeted effort. The daily harvest rate for the confluence area was estimated as:

$$\widehat{HPUE}_c = (1/n) \sum_{i=1}^{n} HPUE_i \qquad (16)$$

where:

n = number of interviewed anglers reporting confluence-area effort,

$HPUE_i$ = confluence-area harvest per hour of effort for angler i.

The same procedure was used to estimate daily river-area harvest rates ($HPUE_r$).

The variance of this estimate was calculated as:

$$\hat{V}(\overline{HPUE}) = \frac{\sum_{i=1}^{n}(HPUE_i - \overline{HPUE})^2}{n(n-1)}. \tag{17}$$

The overall harvest rate for the late run has been historically estimated to provide a general basis for comparing seasonal fishing success among years (Nelson 1985, Hammarstrom and Athons 1989). A weighted harvest rate for the late run was estimated by dividing the total run-specific harvest estimate by the total run-specific effort estimate. The associated variance was then calculated as the variance of a quotient of two random variables.

Spawning Escapement:

The escapement of spawning sockeye salmon to the Russian River drainage was enumerated at the stationary weir at the outlet of Lower Russian Lake. An adjustable gate system allowed fish to be passed individually and counted by the weir operator. During the period of overlap of early and late runs (mid to late July), fish from each run were subjectively identified by degree of external maturation (body color and kype development) and counted separately. Early in each run, adults have not developed the reddish body coloration characteristic of more mature fish passing through the weir later in each run. Therefore, during the period of run overlap at the weir, the last of the early-run fish typically exhibit reddish body coloration while the late-run fish do not. The period of overlap began on 27 July when late-run fish were intermixed with mature, early-run fish and continued through 1 August, after which early-run fish were no longer present.

Biological Data:

Eight time and area strata were sampled for biological data to estimate the age, sex, and length composition of the late run (Table 1). Differences in age composition over time between spatial components have been demonstrated in the past (Carlon and Vincent-Lang 1990, Carlon et al. 1991).

Scales were collected from the preferred area of each sampled fish and placed on adhesive-coated cards (Clutter and Whitesel 1956). The sex and length (measured from the mid-eye to the fork-of-tail to the nearest millimeter) of each sampled fish was also determined and recorded. Scale impressions were made in clear acetate and examined with a microfiche reader for aging. The European method of age description was used to record ages; the numeral preceding the decimal represents the number of freshwater annuli and the numeral following the decimal represents the number of marine annuli. Total age from brood is therefore the sum of the two numbers plus one.

In prior years, the late-run river area harvest was not sampled for age composition. The age composition from the confluence area harvest was used to allocate the river area harvest (Nelson et al. 1986, Carlon and Vincent-Lang 1990). This procedure assumes that the age composition of the confluence harvest represents that of the river area. This assumption was first tested in 1990 and significant differences among age compositions were found in the

Table 1. Temporal components of the recreational harvest and escapement sampled for age composition during the late run of sockeye salmon to the Russian River, 1991.

Return Component	Temporal Delineation
Late-run confluence area harvest	7/29 - 8/07 8/08 - 8/19
Late-run river area harvest	7/29 - 8/07 8/08 - 8/19
Late-run escapement through weir	7/26 - 8/08 8/09 - 8/22 8/23 - 9/11
Escapement spawning between falls and confluence	8/23, 9/04[a]

[a] Escapement not stratified; dates listed are sampling dates.

three sampled areas during some of the temporal strata (Carlon et al. 1991). These sampling procedures were again utilized in 1991 with each area sampled individually and tested for equality among age composition within each temporal stratum. Contingency tests were applied and the null hypotheses of equality of age compositions among components were rejected if calculated tail-area probabilities (P values) were less than 0.10.

Age composition was estimated for each temporal stratum of all spatial return components. The proportion of fish of age group h in stratum i of a component was estimated for each sex as:

$$\hat{P}_{hi} = n_{hi}/n_{Ti}, \tag{18}$$

where:

n_{hi} = the number of legible scales read from sockeye salmon sampled during stratum i and interpreted as age h, and

n_{Ti} = the total number of legible scales read from sockeye salmon sampled during stratum i.

The variance of $\hat{P}_{hi}$ was estimated as (Scheaffer et al. 1978):

$$\hat{V}(P_{hi}) = \hat{P}_{hi}(1-\hat{P}_{hi})/(n_{Ti}-1). \tag{19}$$

The numbers of sockeye salmon (N_{hi}) by age group h were estimated by sex during each temporal stratum i for the late-run escapement using the estimates of the age group proportions (P_{hi}) as defined previously:

$$\hat{N}_{hi} = N_{Ti}\hat{P}_{hi}, \tag{20}$$

where:

N_{Ti} = the total number of sockeye salmon enumerated during stratum i at the weir or spawning downstream from the falls.

The variance of $\hat{N}_{hi}$ was estimated as:

$$\hat{V}(N_{hi}) = N^2_{Ti}\ \hat{V}(P_{hi}). \tag{21}$$

Weighted age composition estimates of weir escapements were generated for the late run by summing estimated numbers by age over temporal strata. For the late run r, the total number of fish of age h (N_{rh}) migrating through the weir was estimated as:

$$\hat{N}_{rh} = \sum_{i=1}^{p} \hat{N}_{hi}, \tag{22}$$

where:

p = the number of temporal strata in the late run r.

The variance of $\hat{N}_{rh}$ was estimated as the sum of the variances of the individual estimates as:

$$\hat{V}(\hat{N}_{rh}) = \sum_{i=1}^{p} V(\hat{N}_{hi}). \tag{23}$$

The proportion of age h adults in the total escapement for the late run r (P_{rh}) migrating through the weir was estimated as:

$$\hat{P}_{rh} = \hat{N}_{rh}/E_r, \tag{24}$$

where:

E_r = the total escapement of the late run r enumerated at the weir.

The variance of $\hat{P}_{rh}$ was estimated as the variance of the product of a random variable ($\hat{N}_{rh}$) and a constant ($1/E_r$) as:

$$\hat{V}(P_{rh}) = (1/E_r)^2\ \hat{V}(N_{rh}). \tag{25}$$

The estimate of the late-run sport harvest (H_{Tt}^*) was allocated using a weighted proportion for each age class h by sex for each spatial component:

$$\hat{N}_h = \hat{H}_{Tt}^* \hat{P}_h, \tag{26}$$

where:

$\hat{H}_{Tt}^*$ = the estimate of total harvest of sockeye salmon during the unstratified spatial/temporal component t,

and:

$$\hat{P}_h = \sum_{i-1}^{p} (\hat{W}_i \hat{P}_{hi})\ ; \tag{27}$$

where:

$$W_i = \frac{\hat{H}_{Ti}}{\hat{H}_{Ts}} \text{ , and} \tag{28}$$

$$\hat{H}_{Ts} = \sum_{i=1}^{p} \hat{H}_{Ti} \text{ ,} \tag{29}$$

where:

$\hat{H}_{Ti}$ = the estimated harvest of sockeye salmon during the individual spatial/temporal strata i.

$\hat{H}_{Ts}$ = the estimated total harvest of sockeye salmon for all spatial/temporal stratum i.

The variance of the estimated proportion of fish harvested which are age class h across all strata is obtained by Goodman's (1960) equation for the product of two random variables:

$$\hat{V}[\hat{P}_h] = \sum_{i=1}^{p} \left\{ \hat{W}^2_i \hat{V}[\hat{P}_{hi}] + \hat{P}^2_{hi}\hat{V}[\hat{W}_i] - \hat{V}[\hat{P}_{hi}]\hat{V}[\hat{W}_i] \right\} \tag{30}$$

where:

$$\hat{V}[\hat{W}_i] = \left[\frac{\hat{H}_{Ti}}{\hat{H}_{Ts}} \right]^2 \left[\frac{\hat{V}[\hat{H}_{Ti}]}{\hat{H}^2_{Ti}} + \frac{\hat{V}[\hat{H}_{Ts}]}{\hat{H}^2_{Ts}} - \frac{2\hat{V}[\hat{H}_{Ti}]}{\hat{H}_{Ti}\hat{H}_{Ts}} \right] \tag{31}$$

and:

$$\hat{V}[\hat{H}_{Ts}] = \sum_{i=1}^{p} \hat{V}[\hat{H}_{Ti}] \text{ , and} \tag{32}$$

$\hat{V}[\hat{H}_{Ti}]$ = the variance of the harvest estimate during the stratified spatial/temporal strata i.

The variance of $\hat{N}_h$ was estimated using the formula for the product of two independent random variables (Goodman 1960):

$$\hat{V}(\hat{N}_h) = \hat{H}^2_{Tt}{}^* \hat{V}(\hat{P}_h) + \hat{P}^2_h \hat{V}(\hat{H}_{Tt}{}^*) - \hat{V}(\hat{P}_h) \hat{V}(\hat{H}_{Tt}{}^*), \tag{33}$$

where:

$\hat{V}(\hat{H}_{Tt}^{*})$ = the variance of the harvest estimate during the unstratified spatial/temporal component t.

Mean length at age was estimated for each spatial/temporal component of the return; the confluence area harvest, the river harvest, and the weir escapement. To determine if individual spatial/temporal samples could be pooled to estimate mean length at age by sex, a Kolomogorov-Smirnov test was utilized. The null hypothesis of no significant difference in relative length frequencies was rejected if the calculated tail-area probabilities (P values) were less than 0.05.

RESULTS

Creel Statistics

Survey Interviews:

Sampling of access locations began on 29 July when the sport fishery was reopened by emergency order. Sampling of all locations continued through the end of the late run on 19 August.

The temporal demarcation point for the late run is determined by the appearance of ocean-bright sockeye salmon in the confluence area of the fishery. Prior to the arrival of the late run, the sport fishery is characteristically slow and water-marked fish dominate the small harvest. The few remaining early-run fish all show signs of prespawning sexual maturity.

During 1991, the appearance of the late-run stocks to the Russian River coincided with a temporary restraining order issued on 24 July which closed the subsistence fishery in Cook Inlet. Subsistence utilization of fish and game resources has priority over other consumptive uses. This priority made it necessary to close the recreational fisheries for sockeye salmon in Cook Inlet until the escapement requirements could be projected for the major Cook Inlet drainages and thereby allow the subsistence fishery to be reopened. Attainment of the escapement goals was projected for the Kenai and Kasilof Rivers on 28 July and the sport fisheries on those rivers were reopened by emergency order on Monday, 29 July. The Russian River, as a part of the Kenai River drainage, was also reopened at this time.

A total of 2,266 anglers were counted as they exited sampled access locations during the 1991 late-run survey (Table 2). Of these, 1,579 (69.7%) were interviewed and 687 (30.3%) were not interviewed. A daily summary of the data collected during the 1991 creel survey is presented in Appendix A1. The total number of interviews collected in the late run represents a 43.8% decrease from 1990 (Carlon et al. 1991). Most of the interviews (55.0%) were obtained from the ferry access location as this location was sampled most intensely and typically accounts for the most effort (Appendix A2).

Anglers exiting via the ferry location fished the confluence area exclusively (100%) during the late run (Appendix A3). Campground access locations were

Table 2. Summary of the number of interviews collected during sampled periods for the Russian River creel survey during the late run, 1991.

Exit Location	Area Fished: Confluence	Area Fished: River	Area Fished: Both	Total Interviews	Anglers Exiting and not Interviewed	Total Anglers Exiting
Ferry	863	0	0	863	526	1,389
Grayling	350	104	50	504	129	633
Rainbow Trout	2	17	0	19	0	19
Pink Salmon	8	134	0	142	26	168
Red Salmon	0	51	0	51	6	57
Late-Run Total	1,223	306	50	1,579	687	2,266

used to fish both areas. However, the majority of anglers exiting these locations fished the river area (89%).

Harvest and Effort:

Estimates of harvest, effort, and variances are presented by stratum (temporal component/access location) in Appendix A4. By examining stratum estimates and associated variance components by access location, it is possible to determine which access locations most affected the relative precision of late-run estimates for both harvest and effort (Table 3). Three access locations (the ferry, Grayling, and Pink Salmon) accounted for most of the harvest during the late run (92.9%). The relative precisions of the late-run harvest and effort estimates were 22% and 20%, respectively (Table 3).

The 1991 late-run harvest estimate was 31,449 (SE = 3,567) sockeye salmon (Table 4). The effort estimate for the late run was 78,849 (SE = 3,567) angler-hours. During the late run, 76% of the harvest was taken from the confluence area and the remaining 24% was taken from the river area (Table 4 and Figure 3). Correspondingly, the effort during the late-run sport fishery was directed primarily to the confluence area (76%) and less so in the river area (24%).

Table 5 documents the weighted harvest per hour of angler effort for both the confluence and river areas in 1991. The estimated HPUE for the late run was 0.399 which reflects an increase in angler catch efficiency of 13.9% over 1990 (Carlon et al. 1991).

Spawning Escapement

A total of 78,175 late-run sockeye salmon passed through the weir (Table 6, Figure 4, and Appendix A5). Transition between the two runs occurred between 27 July and 1 August. Weir enumeration ceased on 11 September. There were an estimated 250 sockeye salmon holding downstream from the weir approximately 100 m and these fish were included in the 11 September total. The migratory timing of the 1991 late run to the Russian River was significantly later than the historical mean (Figure 5). The pattern of daily escapements was also unusual in that the largest count was realized on the first day (Figure 4) of the return.

An estimated 22,267 sockeye salmon were counted during foot surveys of the Russian River downstream from the Russian River falls (Table 6).

The number of coho salmon enumerated through the weir during the late run was 1,540. This figure represents only a partial accounting of the total return as the weir was removed before the completion of the coho salmon migration (Table 6 and Appendix A5).

Biological Data

The late-run escapement through the weir was comprised predominantly of three age groups: age 2.2 (40.9%), age 1.2 (22.2%), and age 2.1 (14.5%) (Table 7). There were significant differences in the age class composition detected between the three temporal sampling strata ($v^2 = 222.33$, df = 10, $P < 0.005$).

Table 3. Estimates of harvest, effort, and associated variances by access location for the late-run Russian River sockeye salmon recreational fishery, 1991.

	Harvest	(%)	Variance of Harvest	(%)	Relative Precision (%)	Effort	(%)	Variance of Effort	(%)	Relative Precision (%)
Ferry	17,686	56	6,793,451	53	29	42,438	54	38,618,414	60	29
Grayling	7,346	23	904,181	7	25	20,835	26	7,811,121	12	26
Rainbow Trout	726	2	227,304	2	128	1,485	2	372,240	1	80
Pink Salmon	4,171	13	3,210,556	25	84	10,208	13	12,667,364	20	68
Red Salmon	1,520	5	1,585,059	13	162	3,883	5	4,701,591	7	109
Total	31,449	100	12,720,551	100	22	78,849	100	64,170,730	100	20

[a] $\alpha = 0.05$

Table 4. Summary of estimated angler-effort and harvest of sockeye salmon during the late run, for each area of the Russian River recreational fishery, 1991.

Component	Confluence Area	River Area	Total	95% Confidence Interval
Effort	60,146	18,703	78,849	63,149 - 94,549
SE	6,822	4,200	8,010	
Harvest	24,022	7,427	31,449	24,459 - 38,439
SE	2,779	2,235	3,567	

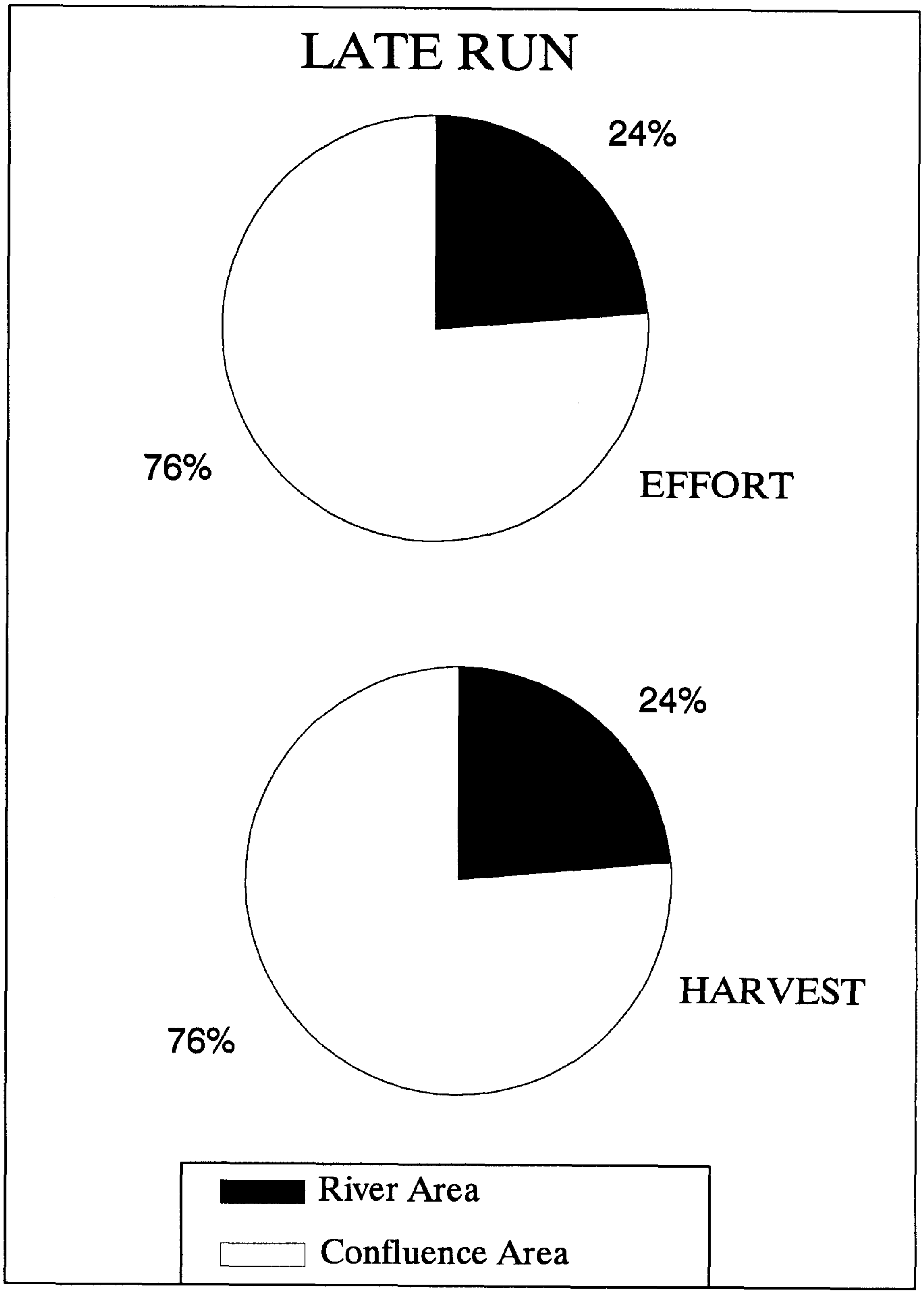

Figure 3. Harvest and angler effort by area for the Russian River late-run sockeye salmon recreational fishery, 1991.

Table 5. Estimated harvest per hour of angler effort (HPUE) by anglers interviewed during the late run, at each location, in the Russian River sockeye salmon recreational fishery, 1991.

Run	Area	Days n^a	Days N^b	Number of Interviews[c]	HPUE	Variance of HPUE
Late	Confluence	15	22	1,248	0.399	0.0042
Late	River	15	22	331	0.397	0.0219
Late	Both			1,579	0.399	0.0037

[a] Number of days on which at least one angler reported fishing effort.

[b] Number of days possible for conducting interviews.

[c] Anglers who fished both areas are represented twice.

Table 6. Escapements of sockeye, coho, and chinook salmon during the late run to the Russian River drainage, 1991.

Component	Dates	Sockeye Salmon	Coho Salmon	Chinook Salmon
Late-Run	07/27 - 09/11	78,175[a]	1,540[b]	12
Downstream[c]	08/23[d]	22,267[e]		19[f]

[a] From 7/27 through 8/01, early-run fish were differentiated from late-run fish based on the degree of external maturation (color).

[b] Only a partial count as the weir was removed prior to completion of migration.

[c] Fish that spawned downstream from the Russian River falls.

[d] Two foot surveys (8/23 and 9/04) were made downstream from the Russian River falls. A greater number of fish were enumerated on 8/23 and the tabulated values are for that date only and thus represent a best minimum estimate.

[e] 21,262 live fish and 1,005 dead fish that spawned downstream from the Russian River falls.

[f] 8 live fish and 11 dead fish enumerated downstream from Russian River falls.

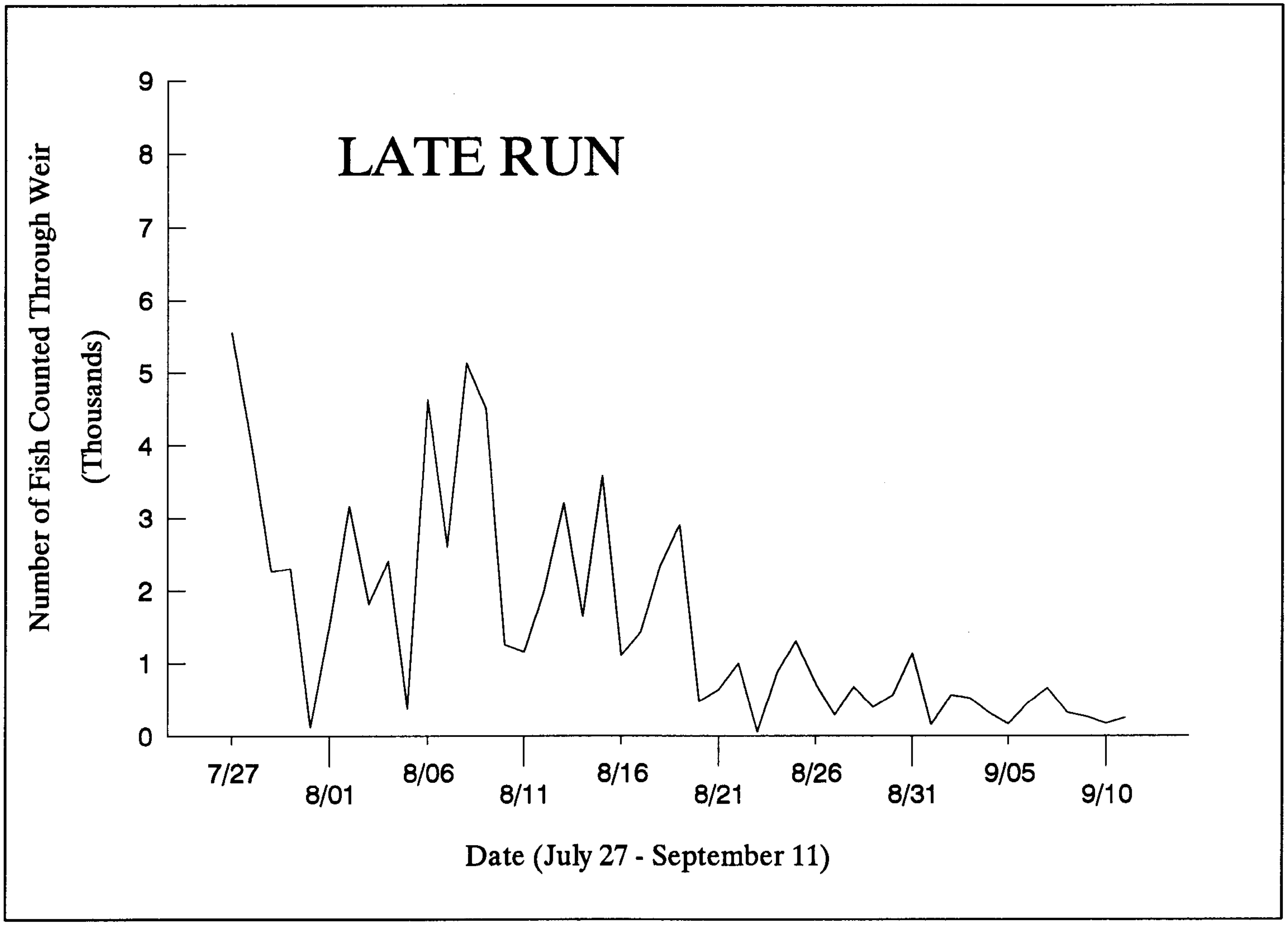

Figure 4. Daily escapement of sockeye salmon through the Russian River weir, 1991.

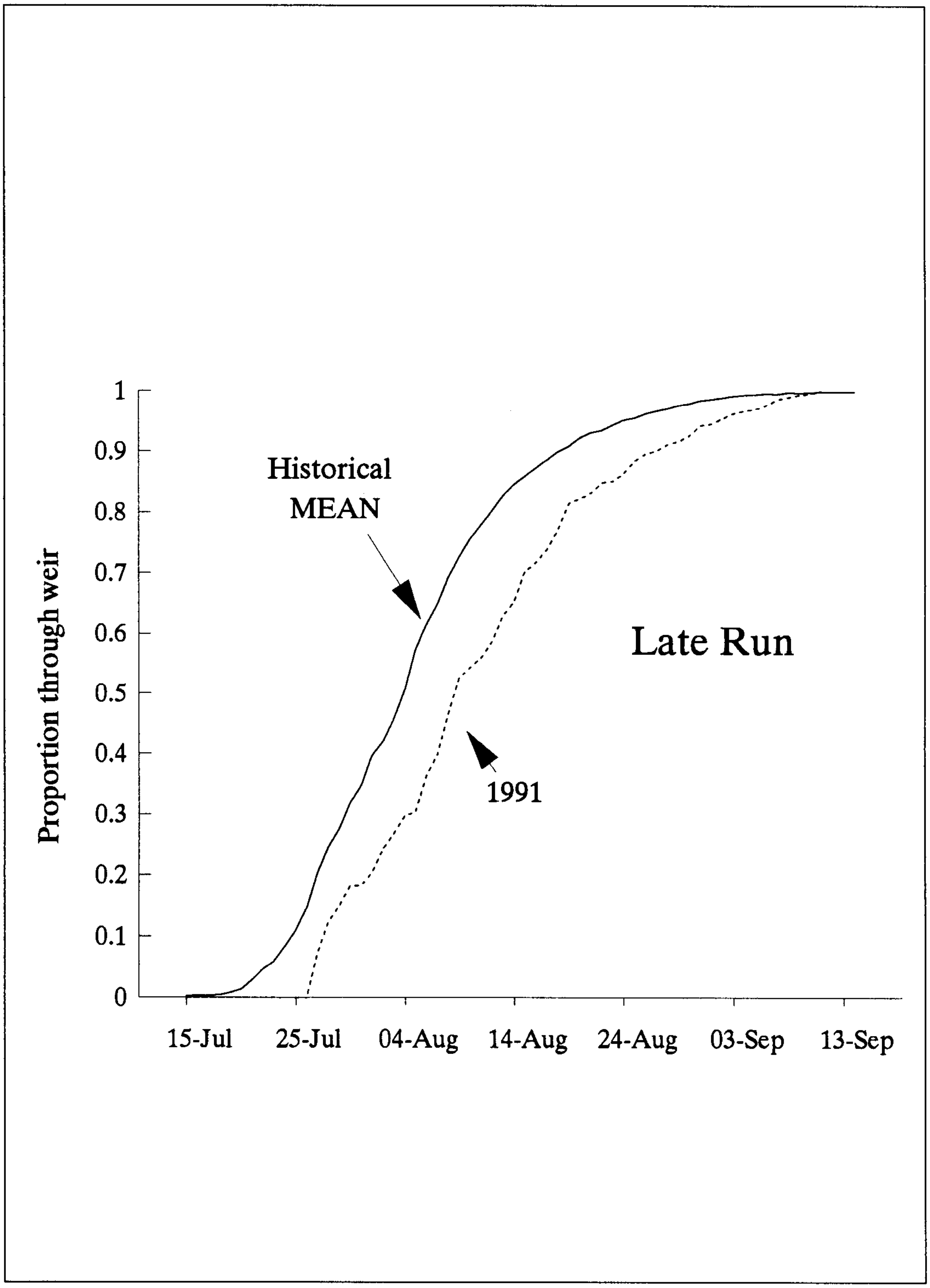

Figure 5. Historical proportions of sockeye salmon escapements through the Russian River weir versus late run, 1991.

Table 7. Estimated age and sex composition of the late-run sockeye salmon escapement through the Russian River weir, 1991.

	Age Group						
Dates	2.3	1.3	2.2	1.2	2.1	1.1	Total
7/26 - 8/08 (n[a] = 195)							
Females							
Sample Size	7	19	11	53		1	91
Percent	3.6	9.7	5.6	27.2		0.5	46.7
Variance of Percent	1.8	4.5	2.7	10.2		0.3	12.8
Number	1,308	3,550	2,055	9,901		187	17,001
Variance of Number	236,757	601,608	364,131	1,353,978		34,902	1,702,637
Males							
Sample Size	18	27	13	40	1	5	104
Percent	9.2	13.8	6.7	20.5	0.5	2.6	53.3
Variance of Percent	4.3	6.1	3.2	8.4	0.3	1.3	12.8
Number	3,363	5,044	2,429	7,473	187	934	19,429
Variance of Number	573,183	816,057	425,659	1,115,422	34,902	170,911	1,702,637
Sexes Combined							
Sample Size	25	46	24	93	1	6	195
Percent	12.8	23.6	12.3	47.7	0.5	3.1	100.0
Variance of Percent	5.8	9.3	5.6	12.9	0.3	1.5	
Number	4,671	8,594	4,484	17,374	187	1,121	36,430
Variance of Number	764,604	1,233,081	738,337	1,706,595	34,902	204,014	

-continued-

Table 7. (Page 2 of 4).

Dates	Age Group 2.3	1.3	2.2	1.2	2.1	Total
8/09 - 8/22 (n^a = 58)						
Females						
Sample Size		1	29			30
Percent		1.7	50.0			51.7
Variance of Percent		3.0	43.9			43.8
Number		516	14,971			15,487
Variance of Number		266,505	3,932,120			3,927,444
Males						
Sample Size	3	1	10		14	28
Percent	5.2	1.7	17.2		24.1	48.3
Variance of Percent	8.6	3.0	25.0		32.1	43.8
Number	1,549	516	5,162		7,227	14,455
Variance of Number	771,462	266,505	2,244,254		2,880,126	3,927,444
Sexes Combined						
Sample Size	3	2	39		14	58
Percent	5.2	3.4	67.2		24.1	100.0
Variance of Percent	8.6	5.8	38.6		32.1	
Number	1,549	1,032	20,133		7,227	29,942
Variance of Number	771,462	523,659	3,464,567		2,880,126	

-continued-

Table 7. (Page 3 of 4).

Dates	Age Group 2.3	1.3	2.2	1.2	2.1	Total
8/23 - 9/11 (n[a] = 134)						
Females						
Sample Size	2		32			34
Percent	2.5		40.5			43.0
Variance of Percent	3.2		30.9			31.4
Number	299		4,781			5,080
Variance of Number	44,071		430,411			437,852
Males						
Sample Size	2		17		26	45
Percent	2.5		21.5		32.9	57.0
Variance of Percent	3.2		21.7		28.3	31.4
Number	299		2,540		3,885	6,723
Variance of Number	44,071		301,631		394,353	437,852
Sexes Combined						
Sample Size	4		49		26	79
Percent	5.1		62.0		32.9	100.0
Variance of Percent	6.2		30.2		28.3	
Number	598		7,321		3,885	11,803
Variance of Number	85,853		420,681		394,353	

-continued-

Table 7. (Page 4 of 4).

Dates	Age Group 2.3	1.3	2.2	1.2	2.1	1.1	Total
Late-run Total (n[a] = 332)							
Females							
Percent	2.1	5.2	27.9	12.7		0.2	48.1
Variance of Percent	0.6	1.5	6.1	3.3		0.1	7.5
Number	1,607	4,066	21,807	9,901		187	37,568
Variance of Number	280,829	868,113	4,726,663	1,353,978		34,902	6,067,934
Males							
Percent	6.7	7.1	13.0	9.6	14.5	1.2	51.9
Variance of Percent	1.9	2.0	3.4	2.6	3.7	0.4	7.5
Number	5,210	5,560	10,131	7,473	11,299	1,121	40,607
Variance of Number	1,388,717	1,082,562	2,971,545	1,115,422	3,309,381	204,014	6,067,934
Sexes Combined							
Percent	8.7	12.3	40.9	22.2	14.5	1.4	100.0
Variance of Percent	2.4	3.3	7.3	5.2	3.7	0.4	
Number	6,817	9,626	31,938	17,374	11,299	1,121	78,175
Variance of Number	1,621,919	1,756,740	4,623,586	1,706,595	3,309,381	204,014	

[a] n = sample size.

Age-1.2 and -1.3 fish dominated the first temporal stratum (47.7% and 23.6%, respectively), but quickly declined with no contribution after that.

The late-run, confluence area harvest was comprised predominantly of age-2.2 (41.1%), age-2.3 (23.9%), and age-1.2 (18.9%) fish (Table 8). There were significant temporal changes detected in the contribution by age (v^2 = 90.4, df = 4, $P < 0.005$), with age-2.2 adults contributing proportionately more during the second stratum (76.9%) than during the first stratum (27.9%).

The late-run, river area harvest was also represented by the age groups of age 2.2 (64.3%) and age 2.3 (21.0%). Age-1.3 adults contributed (6.5%) to the sampled harvest (Table 9). There were also significant temporal changes detected in the contribution by age (v^2 = 35.5, df = 3, $P < 0.005$). The predominant age class (age 2.2) did change significantly between the two temporal strata sampled in the river (50.8% vs. 71.4%).

The age composition of sockeye salmon that spawned in the Russian River downstream from the Russian River falls was estimated for a single stratum (Table 10). The predominant age group was age 1.3, however the combined ages of 2.2, 2.3, and 1.2 contributed a larger proportion than in previous years (Athons and McBride 1987, Hammarstrom and Athons 1988 and 1989, Carlon and Vincent-Lang 1990, Carlon et al. 1991).

Mean length by age and sex was examined individually for the three spatial components sampled during the late run to determine if temporal samples could be pooled to generate single, unbiased estimates for age/sex combinations within each component. A Kolmogorov-Smirnov two-sample test was utilized to determine if there were significant differences between the length frequencies within each age/sex combination. However, some sample sizes were small (less than 30 fish) and the validity of those Kolmogorov-Smirnov test results were suspect. Of 11 possible comparisons which had sufficient sample sizes, only one of the frequency distributions for the age/sex combinations was significantly different. Therefore, samples were pooled to estimate mean length by age and sex (Table 11).

Total Return Statistics

Overall, an estimated 109,624 late-run sockeye salmon returned to the Russian River in 1991 (Table 12). Of these, 42.5% were age 2.2 and 20.3% were age 1.2. Ages 2.3 and 1.3 comprised 12.9% and 12.5% of the return, respectively. Age-2.1 salmon comprised an additional 10.7% of the late run. Spawners below the falls were not included in this total. These fish, which are primarily 3-ocean fish, are more closely associated with the age structure of sockeye salmon spawning in the mainstem Kenai River (Cross et al. 1983, 1985, 1986) and are believed to spend their freshwater residency in Skilak Lake.

DISCUSSION

Relative Run Strength

Total return of the 1991 late run, (harvest plus escapement), approximated that of most recent years (Figure 6). The 1991 return was exceeded only by 6 prior years since record-keeping was formalized in 1963. The 1991 late run

Table 8. Estimated age and sex composition of late-run sockeye salmon harvested from the confluence area of the Russian River recreational fishery, 1991.

	Age Group						
Dates	2.3	1.3	2.2	1.2	2.1	1.1	Total
Late-run Total							
7/29 - 8/19 (n[a] = 319)							
Females							
Sample Size	26	20	113	16		1	176
Percent	9.0	9.0	25.4	10.4		0.8	54.6
Variance of Percent	5.5	5.8	14.7	7.3		0.6	29.2
Number	2,168	2,151	6,108	2,505		186	13,118
Variance of Number	375,375	394,655	1,334,965	497,417		34,606	3,966,812
Males							
Sample Size	31	11	86	11	4		143
Percent	14.9	5.9	15.6	8.5	0.5		45.4
Variance of Percent	9.5	4.1	8.2	6.2	0.1		24.5
Number	3,569	1,418	3,754	2,046	116		10,904
Variance of Number	709,093	260,622	653,951	408,278	3,788		2,988,965
Sexes Combined							
Sample Size	57	31	199	27	4	1	319
Percent	23.9	14.9	41.1	18.9	0.5	0.8	100.0
Variance of Percent	14.0	9.5	27.8	12.4	0.1	0.6	
Number	5,737	3,569	9,862	4,552	116	186	24,022
Variance of Number	1,237,721	709,093	2,884,956	982,270	3,788	34,606	10,433,599

[a] n = sample size.

Table 9. Estimated age and sex composition of late-run sockeye salmon harvested from the river area of the Russian River recreational fishery, 1991.

	Age Group					
Dates	2.3	1.3	2.2	1.2	2.1	Total
<u>Late-run Total</u>						
<u>7/29 - 8/19</u> (n^a = 291)						
Females						
Sample Size	27	11	112	11	1	162
Percent	8.3	3.8	40.8	2.9	0.4	56.2
Variance of Percent	8.3	1.9	86.2	2.4	0.2	167.3
Number	615	280	3,030	216	30	4,171
Variance of Number	75,683	16,700	1,263,764	16,289	917	2,414,787
Males						
Sample Size	39	8	69	4	9	129
Percent	12.7	2.7	23.5	1.2	3.7	43.8
Variance of Percent	13.7	1.2	35.2	0.5	2.1	111.1
Number	947	200	1,749	89	273	3,256
Variance of Number	149,862	9,787	453,361	3,052	17,495	1,518,143
Sexes Combined						
Sample Size	66	19	181	15	10	291
Percent	21.0	6.5	64.3	4.1	4.1	100.0
Variance of Percent	36.9	4.2	205.8	3.9	2.5	
Number	1,562	479	4,778	305	303	7,427
Variance of Number	405,790	41,767	3,100,373	27,759	20,722	7,594,281

[a] n = sample size.

Table 10. Estimated age and sex composition of sockeye salmon spawning downstream from the Russian River falls, 1991.

	Age Group						
Dates	2.3	1.3	2.2	1.2	2.1	1.1	Total
8/27, 9/04[a](n[b] = 117)							
Females							
Percent	2.6	29.9	8.5	21.4			62.4
Number	571	6,661	1,903	4,758			13,893
Standard Error	327	947	578	847			1,002
Males							
Percent	1.7	33.3		2.6			37.6
Number	381	7,422		571			8,374
Standard Error	268	975		327			1,002
Sexes Combined							
Percent	4.3	63.2	8.5	23.9			100.0
Number	952	14,083	1,903	5,329			22,267
Standard Error	423	1,359	578	908			

[a] Sampling took place on these two dates.

[b] n = sample size.

Table 11. Mean length (millimeters) at age, by sex, for the late run of sockeye salmon sampled from the Russian River, 1991.

Component		Age Class 2.3	1.3	2.2	1.2	2.1	1.1
Escapement[a]							
Female	Mean Length	564	570	509	526		493
	SE	3.7	6.1	2.5	3.3		
	Sample Size	9	20	72	53		1
Male	Mean Length	579	583	505	521	371	423
	SE	4.8	4.3	5.4	4.6	3.4	31.8
	Sample Size	23	28	40	40	41	5
Confluence Area Harvest							
Female	Mean Length	558	577	517	517		498
	SE	4.0	4.7	2.1	8.7		
	Sample Size	26	20	113	16		1
Male	Mean Length	587	592	516	527	381	
	SE	4.8	6.8	2.7	5.3	3.8	
	Sample Size	31	11	86	11	4	
River Area Harvest							
Female	Mean Length	574	571	522	506	385	
	SE	4.5	5.1	2.1	6.3		
	Sample Size	27	11	112	11	1	
Male	Mean Length	589	599	527	515	393	
	SE	3.3	7.3	3.1	7.4	15.8	
	Sample Size	39	8	69	4	9	
Downstream Escapement[b]							
Female	Mean Length	546	558	520	518		
	SE	8.7	3.5	4.1	5.0		
	Sample Size	3	35	10	25		
Male	Mean Length	571	588		499		
	SE	19.0	3.2		28.9		
	Sample Size	2	39		3		

[a] Fish that migrated through the weir.

[b] Fish that spawned downstream from Russian River Falls.

Table 12. Estimated age and sex composition of the late run of sockeye salmon to the Russian River, 1991.

	Age Group						
Dates	2.3	1.3	2.2	2.1	1.2	1.1	Total
Late-run Total[a] (n[b] = 942)							
Females							
Percent	4.0	5.9	28.2	0.03	11.5	0.3	50.0
Variance of Percent	0.6	1.1	6.9	0.001	1.7	0.06	13.0
Number	4,390	6,496	30,945	30	12,623	373	54,856
Variance of Number	731,887	1,279,468	7,325,392	917	1,867,684	69,508	12,449,533
Males							
Percent	8.9	6.5	14.3	10.7	8.8	0.9	50.0
Variance of Percent	2.0	1.2	3.6	2.9	1.4	0.1	2.7
Number	9,726	7,178	15,633	11,688	9,608	934	54,768
Variance of Number	2,247,672	1,352,971	4,078,857	3,330,665	1,526,753	170,911	10,575,042
Sexes Combined							
Percent	12.9	12.5	42.5	10.7	20.3	1.2	100.0
Variance of Percent	2.9	2.2	10.7	2.9	2.7	0.2	
Number	14,116	11,405	46,578	11,718	22,231	1,307	109,624
Variance of Number	3,265,430	1,327,002	10,608,915	3,333,892	2,716,625	238,620	12,720,551

[a] Confluence area harvest + river harvest + escapement through weir.

[b] n = sample size.

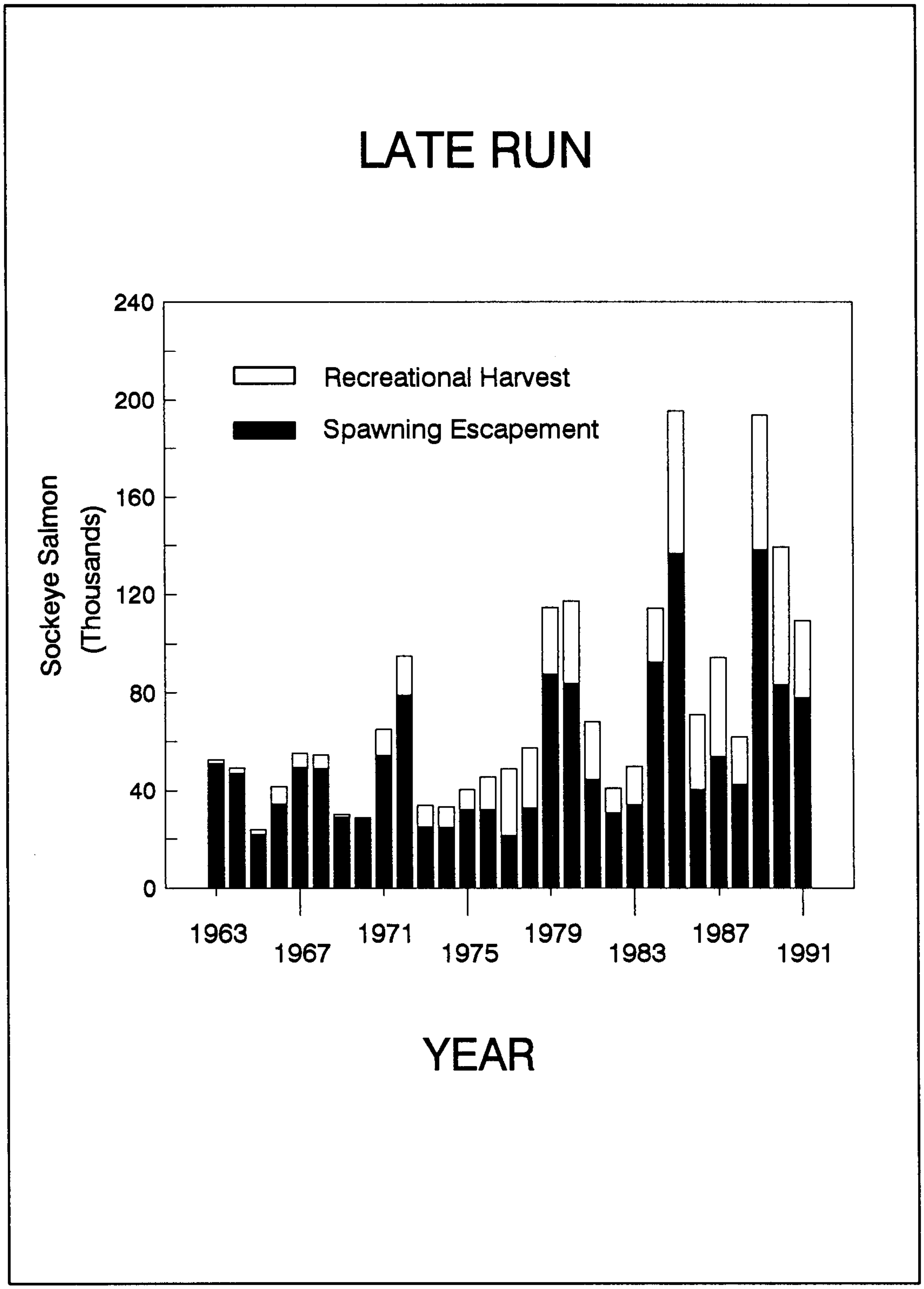

Figure 6. Historical returns of sockeye salmon for the late run to the Russian River.

follows a general trend, beginning in 1978, of greater numbers of sockeye salmon returning to the Russian River system.

Sample Design

Creel Survey:

An underlying assumption necessary for total harvest estimates is that all anglers exit the fishery through one of the five sampled access locations. While anglers were observed using other exit locations, the level at which this occurred during the 1991 late run appeared to be insignificant within the Russian River.

Observations of angler activity during the unsampled hours of 0000 to 0600 hours indicated that, generally, only small numbers of fishermen were engaged in fishing at those hours during the 1991 late run. However, random observations of access locations during the nighttime period should be continued in the future. This will provide additional information regarding any possible changes in angler use patterns which might prove useful in further refining the survey.

Age Composition:

The accurate assessment of the age composition of the sockeye salmon return is needed to establish accurate brood tables for the Russian River system. The sampling of time and area components adopted in 1990 was continued in 1991. This increase in sampling intensity over prior years is an effort to achieve more accurate age composition estimates. Significant temporal changes in age composition were detected within spatial components as well as changes between spatial components within temporal strata in 1990 (Carlon et al. 1991).

Age composition of the confluence and river harvests and the weir escapement clearly differed during the late run in 1991. Therefore, it was not appropriate to use the age composition from one area to apportion the harvest estimates or escapements for any other spatial component and each area was allocated independently. The indication that age compositions differed over time within the spatial components of the fishery dictated that samples could not be pooled to allocate the estimated harvest in the confluence or the river areas. A stratified harvest estimate based upon the age-weight-length (AWL) sample periods was calculated for each spatial component and a weighted proportion calculated for each of the temporal/spatial strata. The weighted proportions were then applied to the single, unstratified harvest estimates for both the confluence and river areas. This method allowed for an unbiased allocation of the estimated harvests from the different areas of the Russian River.

Changes in age composition were detected between and among times and areas of the late-run fishery in 1991. It is therefore recommended that the sampling of the individual spatial components be continued at the present sampling intensity. This will help to better estimate the numbers of sockeye salmon returning by age and sex and to improve the evaluation of those differences over time. The end result will be improved accuracy of brood production information necessary for the long term management of the Russian River system.

Management of the Fishery

The utilization of migratory timing statistics from weir counts and fishery harvest rates should be continued. The technique of fitting a migratory timing distribution function to count and harvest rate data has been used successfully in the Kenai River to project escapements of chinook salmon (McBride et al. 1989) and was adapted from techniques used to quantify migratory timing of chinook salmon in the Yukon River drainage (Mundy 1982). It is recommended that this technique be implemented experimentally in 1992 and subsequent years to begin evaluation of its value in managing the Russian River sockeye salmon resource.

ACKNOWLEDGEMENTS

Jay Carlon provided consistent insight and invaluable technical support during the entire project.

Larry DuBois operated the Russian River weir, collected climatological information and age, sex, and length data and assisted with stream surveys. His mechanical and carpentry skills were essential to the operation of the remote facility.

Paul Zallek collected creel survey data and age, sex, and length data from the fishery and monitored the fishery for regulation violations. His detailed observations of the fishery were invaluable to the conduct of the creel census and the management of the sockeye salmon resource.

Colleen O'Brien also collected creel survey data and age, sex, and length data from the fishery. Her enthusiasm and conduct while performing her responsibilities proved to be an asset to the Russian River project.

Steve Hammarstrom and Dave Athons, by virtue of their extensive experience with this project, provided invaluable, concrete advice about the day-to-day operations of the study as well as logistical support.

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APPENDIX A

Selected Summaries of Fishery and Escapement Data
from the Russian River, 1991.

Appendix A1. Daily sample statistics for the 1991 Russian River late-run creel survey.

Location Exited[a]	Date	Period[b]	Location Fished[c]	Location fished angler stats.[d] m_{hij}	M_{hij}	a_{hij}	p_{hij}	Effort Mean	Effort Variance	Effort Total	Harvest Mean	Harvest Variance	Harvest Total
1	910729	4	1	0	0	24	0	0	0	0	0	0	0
1	910729	2	1	0	0	6	0	0	0	0	0	0	0
1	910731	4	1	0	0	23	0	0	0	0	0	0	0
1	910731	6	1	0	0	26	0	0	0	0	0	0	0
1	910802	5	1	0	0	80	0	0	0	0	0	0	0
1	910802	6	1	0	0	43	0	0	0	0	0	0	0
1	910804	2	1	0	0	15	0	0	0	0	0	0	0
1	910804	5	1	0	0	137	0	0	0	0	0	0	0
1	910806	2	1	0	0	65	0	0	0	0	0	0	0
1	910808	1	1	0	0	0	0	0	0	0	0	0	0
1	910808	6	1	0	0	39	0	0	0	0	0	0	0
1	910810	1	1	0	0	0	0	0	0	0	0	0	0
1	910810	4	1	0	0	47	0	0	0	0	0	0	0
1	910814	3	1	0	0	3	0	0	0	0	0	0	0
1	910814	4	1	0	0	18	0	0	0	0	0	0	0
2	910729	4	1	11	15	8	0.55	4.091	4.941	63	0.545	0.473	8
2	910729	2	1	8	9	3	0 .364	3	1.071	27	1	0.857	9
2	910804	3	1	5	9	30	0 .119	2.8	4.2	24	0.6	1.8	5
2	910804	1	1	2	3	8	0 .125	1	0.5	3	2	2	6
2	910807	5	1	11	11	0	0.18	3.5	4.5	39	0.727	1.018	8
2	910807	3	1	10	11	7	0 .196	3.1	3.378	35	0.8	1.733	9
2	910810	1	1	7	7	0	0 .269	1.143	0.06	8	0.143	0.143	1
2	910810	4	1	11	20	38	0 .244	4.364	8.055	89	0.636	1.055	13
2	910812	4	1	9	10	2	0 .265	4.778	3.444	46	1.222	1.694	12
2	910812	5	1	2	3	14	0 .041	3	0	8	0.5	0.5	1
2	910813	6	1	11	16	10	0 .478	2.045	0.723	32	1.545	1.073	24
2	910813	1	1	1	1	0	0 .333	1	0	1	3	0	3
2	910816	3	1	12	13	5	0 .286	2.917	1.629	39	1.25	1.477	17
2	910816	2	1	16	18	3	0 .762	2.281	0.399	42	0.813	1.496	15
2	910819	5	1	13	14	1	0 .542	3.462	2.353	47	1.615	2.09	22

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Appendix A1. (Page 2 of 4).

Location Exited[a]	Date	Period[b]	Location Fished[c]	Location fished angler stats.[d] m_{hij}	M_{hij}	a_{hij}	P_{hij}	Effort Mean	Effort Variance	Effort Total	Harvest Mean	Harvest Variance	Harvest Total
3	910804	5	1	6	6	0	0 .857	1	0	6	0	0	0
3	910804	1	1	2	2	0	0 .667	2.5	0	5	1	2	2
3	910813	2	1	8	8	0	1	3.063	0.388	25	2	1.143	16
3	910813	6	1	1	1	0	1	4.5	0	5	0	0	0
4	910730	6	1	0	0	2	0	0	0	0	0	0	0
4	910730	1	1	6	8	2	1	3.167	2.467	25	0.333	0.267	3
4	910805	2	1	6	9	3	1	1.833	0.567	17	2.167	0.967	20
4	910805	5	1	60	62	2	1	3.675	1.982	228	1.683	1.034	104
4	910811	3	1	25	30	5	1	3.42	1.827	103	1.64	1.907	49
4	910811	1	1	3	4	1	1	1.667	0.333	7	1.667	0.333	7
4	910817	6	1	18	19	1	1	3.472	3.867	66	0.944	1.232	18
4	910817	5	1	16	24	10	0 .762	4.188	7.129	99	1.438	1.729	34
5	910803	1	1	5	5	0	1	1.3	0.45	7	0.2	0.2	1
5	910803	6	1	3	3	0	1	0.5	0	2	0	0	0
5	910809	3	1	10	10	0	1	4.45	7.914	45	3	0	30
5	910809	4	1	14	16	2	1	4.357	7.67	70	1.643	1.94	26
5	910815	3	1	11	13	2	1	2.636	0.455	34	0.909	0.891	12
5	910815	4	1	8	10	2	1	2	0	20	0	0	0
1	910729	4	2	52	76	24	1	5.058	7.202	384	0.865	1.334	66
1	910729	2	2	12	18	6	1	3.583	0.356	65	0.25	0.205	5
1	910731	4	2	44	67	23	1	4.08	1.034	273	1.909	1.48	128
1	910731	6	2	46	72	26	1	3.793	1.351	273	2.043	1.109	147
1	910802	5	2	84	164	80	1	5.369	9.814	881	1.952	1.419	320
1	910802	6	2	70	113	43	1	3.243	1.578	366	1.714	1.28	194
1	910804	5	2	104	241	137	1	4.385	5.001	1057	1.971	1.388	475
1	910804	2	2	72	87	15	1	3.382	3.842	294	2.306	1.201	201
1	910806	2	2	155	220	65	1	3.555	2.145	782	1.619	1.445	356
1	910808	6	2	118	157	39	1	4.559	4.586	716	1.627	1.415	255
1	910808	1	2	2	2	0	1	9	0	18	3	0	6
1	910810	1	2	3	3	0	1	4	0.75	12	2	3	6

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Appendix A1. (Page 3 of 4).

Location Exited[a]	Date	Period[b]	Location Fished[c]	Location fished angler stats.[d] m_{hij}	M_{hij}	a_{hij}	p_{hij}	Effort Mean	Effort Variance	Effort Total	Harvest Mean	Harvest Variance	Harvest Total
1	910810	4	2	54	101	47	1	5.111	3.355	516	1.907	1.482	193
1	910814	4	2	30	48	18	1	3.7	0.838	178	1	1.379	48
1	910814	3	2	17	20	3	1	3	1.156	60	0.941	1.559	19
2	910729	4	2	9	13	8	0.45	5.222	2.632	66	0.556	1.278	7
2	910729	2	2	16	18	3	0.727	3.094	0.807	56	0.875	1.317	16
2	910804	1	2	15	23	8	0.938	1.733	1.424	39	2.267	1.495	51
2	910804	3	2	37	63	30	0.881	3.014	2.076	191	1.081	1.854	69
2	910807	5	2	55	55	0	0.902	5.164	8.621	284	2.182	1.114	120
2	910807	3	2	46	52	7	0.902	3.652	2.91	191	1.848	1.732	97
2	910810	1	2	22	22	0	0.846	4.182	9.584	92	2.227	1.517	49
2	910810	4	2	37	68	38	0.822	4.149	6.206	283	1.189	1.602	81
2	910812	4	2	25	26	2	0.735	3.92	2.41	104	1.24	1.357	33
2	910812	5	2	49	63	14	1	5	5.24	315	1.102	1.26	69
2	910813	6	2	14	20	10	0.609	2.786	2.72	56	1.643	1.478	33
2	910813	1	2	2	2	0	0.667	3.5	0	7	3	0	6
2	910816	3	2	30	34	5	0.714	2.917	1.553	98	1.267	1.444	43
2	910816	2	2	5	6	3	0.238	4	0	23	2.6	0.8	15
2	910819	5	2	13	14	1	0.542	6.346	10.016	86	1	1	14
3	910804	5	2	1	1	0	0.143	3.5	0	4	1	0	1
3	910804	1	2	1	1	0	0.333	1.5	0	2	3	0	3
3	910813	2	2	0	0	0	0	0	0	0	0	0	0
3	910813	6	2	0	0	0	0	0	0	0	0	0	0
4	910730	6	2	3	5	2	1	5.667	5.333	28	1.333	0.333	7
4	910730	1	2	0	0	2	0	0	0	0	0	0	0
4	910805	5	2	0	0	2	0	0	0	0	0	0	0
4	910805	2	2	0	0	3	0	0	0	0	0	0	0
4	910811	3	2	0	0	5	0	0	0	0	0	0	0
4	910811	1	2	0	0	1	0	0	0	0	0	0	0
4	910817	6	2	0	0	1	0	0	0	0	0	0	0
4	910817	5	2	5	7	10	0.238	6.3	1.575	47	1.6	0.8	12

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Appendix A1. (Page 4 of 4).

Location Exited[a]	Date	Period[b]	Location Fished[c]	Location fished angler stats.[d] m_{hij}	M_{hij}	a_{hij}	P_{hij}	Effort Mean	Effort Variance	Effort Total	Harvest Mean	Harvest Variance	Harvest Total
5	910803	6	2	0	0	0	0	0	0	0	0	0	0
5	910803	1	2	0	0	0	0	0	0	0	0	0	0
5	910809	3	2	0	0	0	0	0	0	0	0	0	0
5	910809	4	2	0	0	2	0	0	0	0	0	0	0
5	910815	3	2	0	0	2	0	0	0	0	0	0	0
5	910815	4	2	0	0	2	0	0	0	0	0	0	0

[a] Access codes: 1 = Ferry, 2 = Grayling, 3 = Rainbow Trout, 4 = Pink Salmon, and 5 = Red Salmon.

[b] Period codes: 1 = 0600-0900 hours, 2 = 0900-1200 hours, 3 = 1200-1500 hours, 4 = 1500-1800 hours, 5 = 1800-2100 hours, and 6 = 2100-2400 hours.

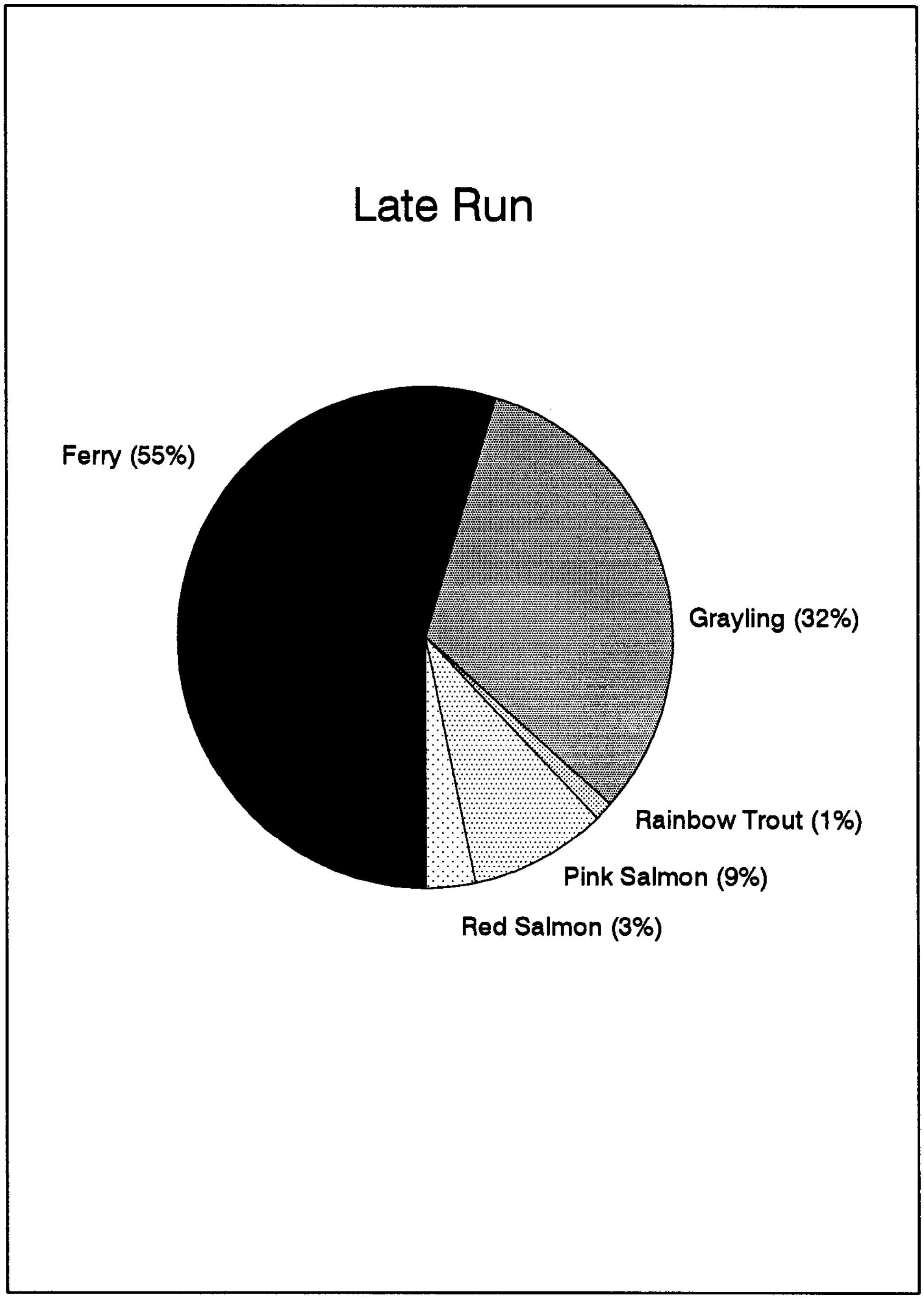
[c] Area Fished codes: 1 = river area, 2 = confluence area.

[d] Angler statistics: m_{hij} = number of anglers interviewed.

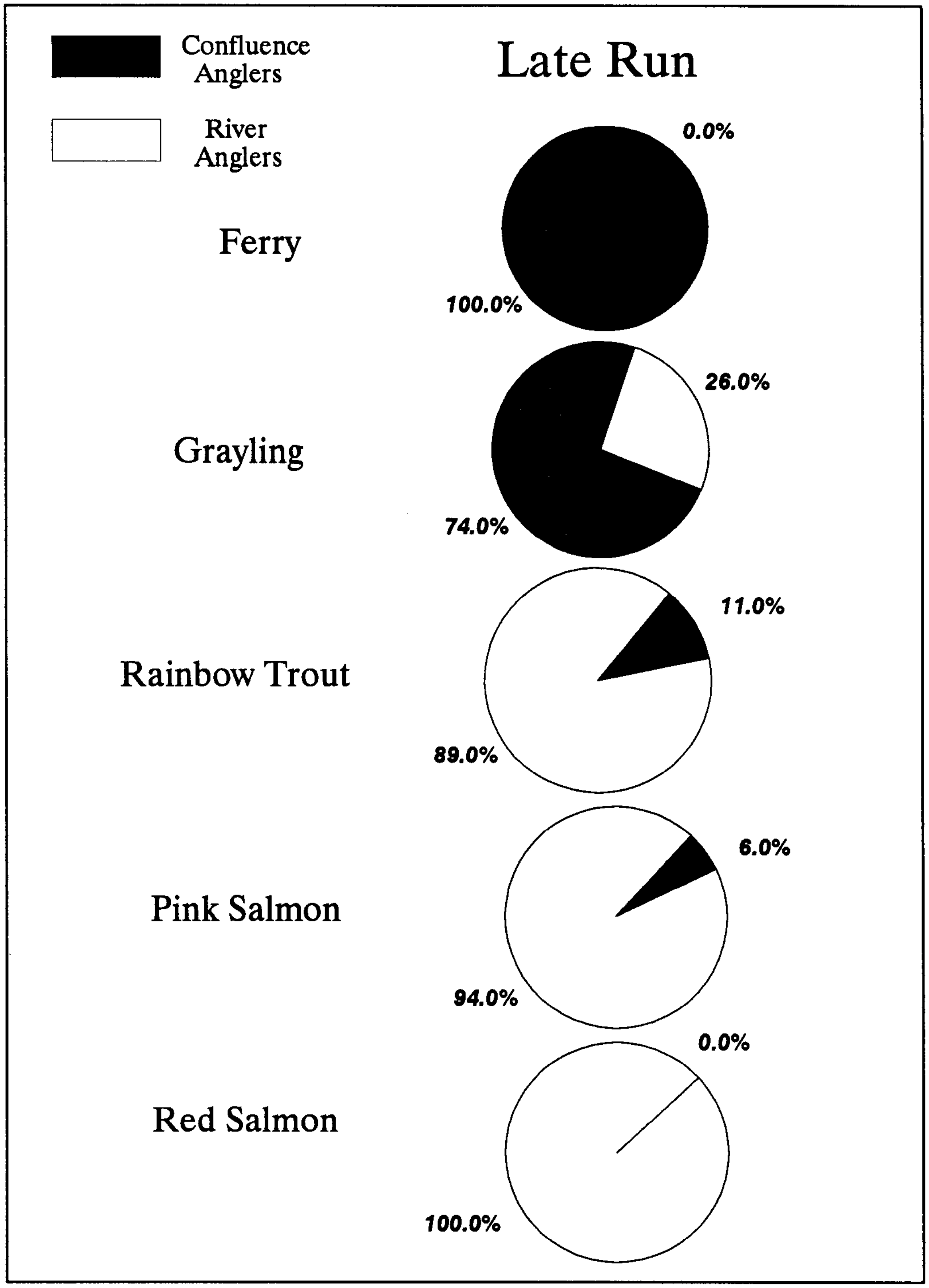
M_{hij} = estimated number of anglers exiting by location fished.

a_{hij} = number of anglers exiting and not interviewed.

P_{hij} = proportion of interviewed anglers by location fished.



Appendix A2. Relative proportions of interviews collected at the five access locations to the Russian River late-run sockeye salmon recreational fishery, 1991.



Appendix A3. Relative proportions of confluence and river anglers interviewed during the creel survey by access location, and area fished, late run, 1991.

Appendix A4. Temporal harvest and effort estimates for the 1991 Russian River late-run sockeye salmon recreational fishery by area and access location.

Location Exited	Temporal Period	D[a]	d[b]	Mean	Variance	Estimated Total Effort	Estimated Total Variance	Variance Components Days	%	Periods	%	Anglers	%
Late-run river effort:													
Ferry	7/29-8/19	17	8										
Grayling	7/29-8/19	22	8	206	7,336	4,527	459,590	282,446	62	175,373	38	1,771	0
Rainbow	7/29-8/19	22	2	60	1,458	1,320	347,226	320,760	92	26,466	8	0	0
Pink salmon	7/29-8/19	22	4	408	103,962	8,973	12,128,827	10,292,285	85	1,834,746	15	1,797	0
Red salmon	7/29-8/19	22	3	176	33,468	3,883	4,701,591	4,663,145	99	38,037	1	409	0
		Total 7/29-8/19				18,703	17,637,234						
		Late-run river				18,703	17,637,234						
Late-run confluence effort:													
Ferry	7/29-8/19	17	8	2,496	882,416	42,438	38,618,414	16,876,211	44	21,712,855	56	29,348	0
Grayling	7/29-8/19	22	8	741	138,930	16,308	7,351,531	5,348,810	73	1,997,415	27	5,307	0
Rainbow	7/29-8/19	22	2	8	113	165	25,014	24,750	99	264	1	0	0
Pink salmon	7/29-8/19	22	4	56	4,448	1,235	538,537	440,307	82	97,846	18	385	0
Red salmon	7/29-8/19	22	3										
		Total 7/29-8/19				60,146	46,533,496						
		Late-run confluence				60,146	46,533,496						
		Late-run total				78,849	64,170,730						

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Appendix A4. (Page 2 of 2).

Location Exited	Temporal Period	D[a]	d[b]	Mean	Variance	Estimated Total Harvest	Estimated Total Variance	Variance components Days	%	Periods	%	Anglers	%
Late-run river harvest:													
Ferry	7/29-8/19	17	8										
Grayling	7/29-8/19	22	8	66	296	1,447	23,626	11,399	48	11,764	50	463	2
Rainbow	7/29-8/19	22	2	27	882	594	211,200	194,040	92	17,160	8	0	0
Pink salmon	7/29-8/19	22	4	176	28,994	3,866	3,177,112	2,870,386	90	306,068	10	657	0
Red salmon	7/29-8/19	22	3	69	11,326	1,520	1,585,059	1,578,119	100	6,796	0	144	0
		Total 7/29-8/19				7,427	4,996,997						
		Late-run river				7,427	4,996,997						
Late-run confluence harvest													
Ferry	7/29-8/19	17	8	1,040	225,823	17,686	6,793,451	4,318,862	64	2,465,447	36	9,142	0
Grayling	7/29-8/19	22	8	268	20,758	5,899	880,555	799,190	91	79,215	9	2,150	0
Rainbow	7/29-8/19	22	2	6	72	132	16,104	15,840	98	264	2	0	0
Pink salmon	7/29-8/19	22	4	14	276	305	33,444	27,311	82	6,069	18	65	0
Red salmon	7/29-8/19	22	3										
		Total 7/29-8/19				24,022	7,723,554						
		Late-run confluence				24,022	7,723,554						
		Late-run total				31,449	12,720,551						

[a] D = days possible in a stratum.

[b] d = days sampled in a stratum.

Appendix A5. Daily escapement of sockeye, coho, and chinook salmon through the Russian River weir during the late run, 1991.

Date	Early-Run Sockeye[a]	Late-Run Sockeye	Coho	Chinook
7/27	206	5,560		
7/28	112	4,020		
7/29	39	2,271		
7/30	34	2,303		
7/31	2	122		
8/01	30	1,542		
8/02		3,185		
8/03		1,848		
8/04		2,468		3
8/05		377		
8/06		4,744	1	1
8/07		2,669		
8/08		5,321		
8/09		4,681	6	1
8/10		1,371	4	1
8/11		1,293	2	
8/12		2,079	6	
8/13		3,379	7	
8/14		1,763		
8/15		3,892	37	2
8/16		1,238	4	
8/17		1,566	6	2
8/18		2,595	17	
8/19		3,441	40	
8/20		559	9	
8/21		709	9	
8/22		1,376	37	1
8/23		90		
8/24		1,041	16	
8/25		1,706	12	
8/26		888	6	1
8/27		336	3	
8/28		876	7	
8/29		421	2	
8/30		653		
8/31		1,386	26	
9/01		229	2	
9/02		692	5	
9/03		606	6	

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Appendix A5. (Page 2 of 2).

Date	Early-Run Sockeye[a]	Late-Run Sockeye	Coho	Chinook
9/04		350	11	
9/05		182	7	
9/06		530	28	
9/07		725	105	
9/08		359	99	
9/09		291	288	
9/10		192	332	
9/11		250[b]	400[c]	
Totals		78,175	1,540	12

[a] From 7/27 through 8/01, early-run fish were differentiated from late-run fish based on degree of external maturation, i.e., body coloration and kype development.

[b] An estimated 250 sockeye salmon remained downstream from the weir when it was dismantled on 9/11/91.

[c] An estimated 400 coho salmon remained downstream from the weir when it was dismantled on 9/11/91.